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A Study on DTC with solar PV cell as Input Power

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Abstract:

Direct Torque Control (DTC) is an AC drive control method especially designed to provide fast and robust responses. In this paper a progressive algorithm for direct torque control of three- phase induction drive system supplied by photovoltaic arrays using voltage source inverter to control motor torque and flux with maximum power point tracking at different level of insolation is presented. Experimental results of the new DTC method obtained by an experimental rapid prototype system for drives are presented. Simulation and experimental results confirm that the proposed system gives quick, robust torque and speed responses at constant switching frequencies.

Keywords—Photovoltaic (PV) array, direct torque control (DTC), constant switching frequency, induction motor, maximum power point tracking (MPPT).

In present, energy decreases and tend to be more expensive. Therefore, renewable energy is an alternative choice. Especially, solar energy is widely used. PV is popular used because of clean energy, without pollution of environment, no danger for human and long life of using [1], [2]. To use the solar module effectively it is important to match the load to draw the maximum power at given solar irradiance level and temperature. Controlled DC-DC converters (boost- buck-buck/boost) are used ensure source load matching. An operating point of the module can be shifted by changing the duty ratio using MPPT. Several techniques like Perturb and observe (P&O), incremental conductance technique, fuzzy logic control, and artificial neural network have been presented [3]-[8]. PV system is always used in two applications. One is electrical generation in rural area and two is water pump system which is used in water treatment system and irrigation system in agriculture. The mostly used ones are water pump systems which are supplied by PV array use DC motor because they can be coupled directly to the PV array. However, the disadvantages of DC motor are expensive and high maintenance cost, therefore induction motor has replaced it.

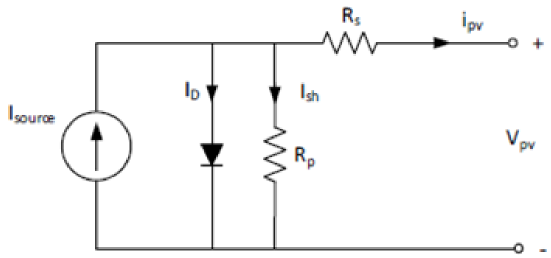

Fig. 1 PV model

In the beginning, several strategies for adjustable speed drives have been introduced like field oriented control, direct self-control (DSC) and DTC based space vector modulation [16]-[22]. Simplicity, high dynamic performance, quick torque response, as well as the fact that there is no need for co- ordinate transformation, voltage, or current decoupling and no need for an encoder are several advantages for DTC leading to remarkable commercial applications.

In this paper, a boost DC-DC converter using a power MOSFT as switching device is used [23]-[25]. A hybrid hysteresis current control with incremental conductance technique for MPPT is proposed. The torque and flux controller design for the overall DTC for induction motor has been investigated. The realization of excellent dynamic torque and flux response is presented.

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PV Module

A practical PV array consists of a collection of solar cells connected in series and/or parallel. An equivalent circuit model for a solar cell is shown in Fig. 1, it is derived as the key element is the current source generating the photovoltaic current (Ipv). The model consists of a current source (Isource), a diode, shunt resistor Rp and a series resistance (Rs) .

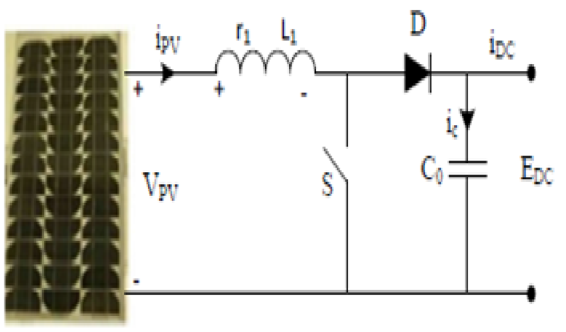

Fig. 2 Boost converter MPPT topology

BOOST CONVERTER

The topology of boost converter is shown in Fig. 2. For this converter the output voltage is always higher than the input PV voltage. Power flow is controlled by means of the on/off duty cycle of the switching transistor. This converter topology can be used in conjunction with lower PV voltages. No extra blocking diode is necessary when the boost topology is used.

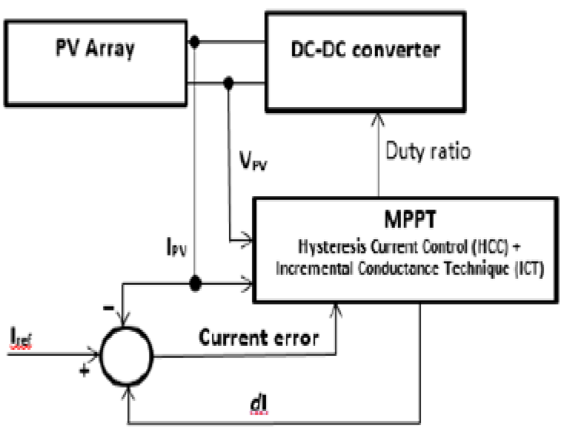

Fig. 3 Proposed MPPT algorithm

The boost converter is described by three modes of operation, on or off. When the switch S is on (Pattern I), the energy from the PV is stored in the inductor L1. When the switch S is off (Pattern II), the energy is delivered to the capacitor C. The Pattern (I), of the boost converter can be expressed by the following equations (S is on and D is off)

Proposed Current Based Peak Power Tracking

In this method, the approximately linear relationship between reference maximum power point current (Iref) and the short circuit current (Isc) of the PV array under varying insolation and temperature levels is given by [5]-[6] where; K1 : constant of proportionally which depends on the characteristic of the PV array.

Fixed step size will be used which works well under constant irradiance but it has worse behaviors under partial cloudy days [7]. Therefore, the irradiance must be measured to perturb the operation voltage. In this paper, a hybrid hysteresis current control (HCC) and incremental conductance technique (ICT) based maximum power point tracker is designed and implemented to get the benefit from the fast response of the current based tracker, as shown in Fig. 3.The controller loop regulates the PV voltage of the converter and minimizes the error between reference current and the measured current by adjusting the duty cycle. At changing conditions, a variable of reference value is used, and the reference current is expressed as:

V. DTC Principle of Operation

Fig. 4 shows a schematic diagram of a closed loop direct torque control system. The torque command (T*) is delivered from the PI-speed controller and fed to the torque comparator and compared with the torque developed from the motor. Also, the stator flux command (ψs*) is compared with the actual stator flux (ψs). By using three variables (torque error, flux error, and the angle of stator flux position (φn), the operating point can be obtained,

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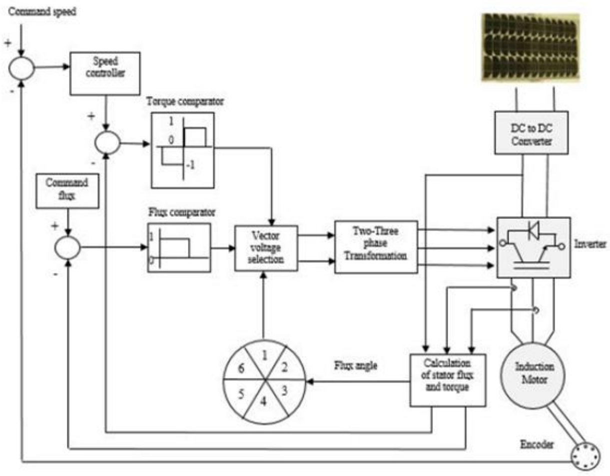

Fig. 4 Block diagram of improved DTC for induction motor drive

The DTC is obtained by adequate selection between active and zero voltage vectors. Hence, when the torque Td is small compared with T* it is necessary to increase Td as fast as possible by applying the fastest vector. On the other hand, when Td reaches T* it is better to decrease Td as slowly as possible. Thus the output of the torque controller can be classified as follows [20];

The output of the torque controller is a three levels hysteresis comparator. The inverter output voltage are given by the outputs of the flux and torque comparators and the angle Φ_.

Simulation Results

A MATLAB/SIMULINK models has been developed to examine the control algorithms. The controller simulation uses the parameters of an experimental laboratory prototype, which is listed in the appendix. The PV module is made up of 72 multi-crystalline silicon solar cells in series and it provides 150W of nominal maximum power.

The performances of the proposed method have been tested in transient and steady state under identical operation conditions. The possibility of using only forward voltage vectors with zero vectors to obtain positive speed has been tested as well. The following figures show clearly the improvements which can be obtained by the proposals presented in this paper. In the respective simulations, however, only the torque control behavior was investigated. More simulations have been performed considering the flux locus, the torque behavior, stator current, and motor speed.

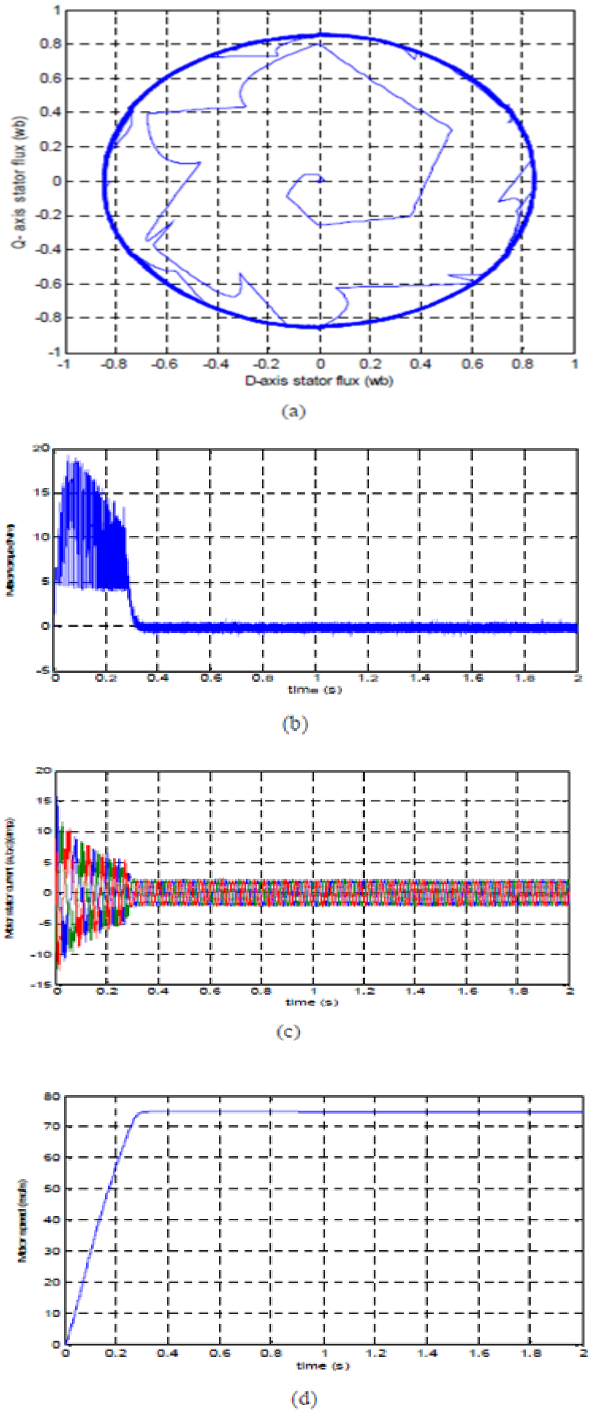

Fig. 5 Performance of IM under no load (a) d-q stator flux,(b) Developed motor torque (c) Three phase stator motor current (d) Motor speed

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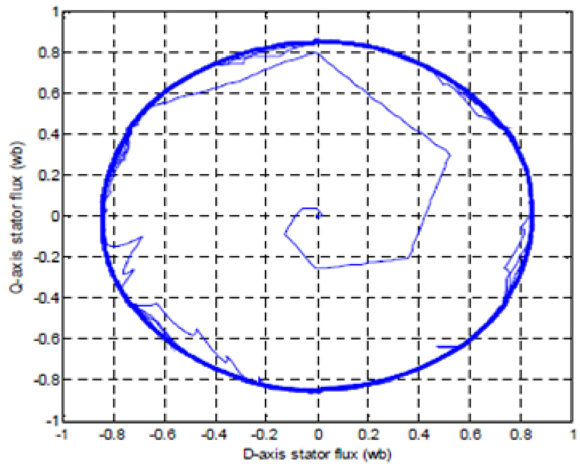

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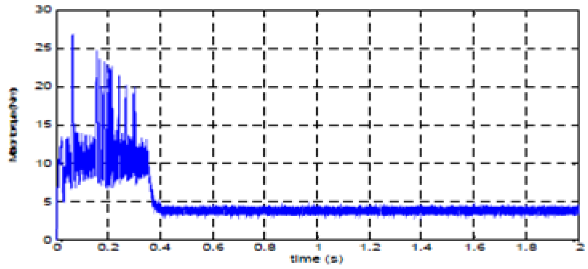

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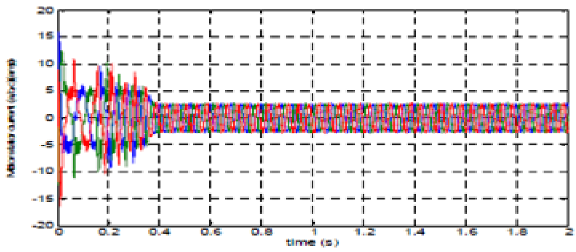

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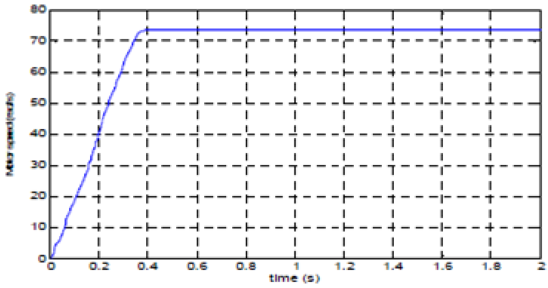
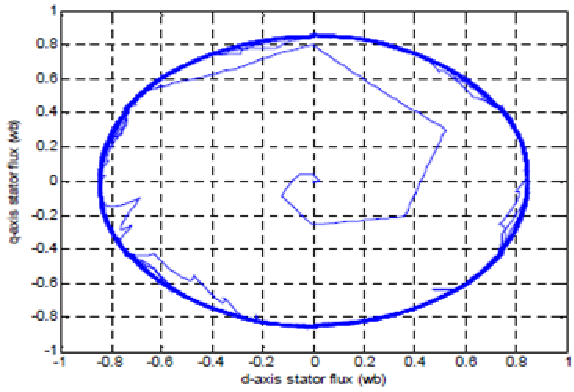


(d)

Fig. 6 Performance of IM under load 4 N.m. (a) d-q stator flux (b) Developed motor torque (c) Three phase stator motor current (d) Motor speed



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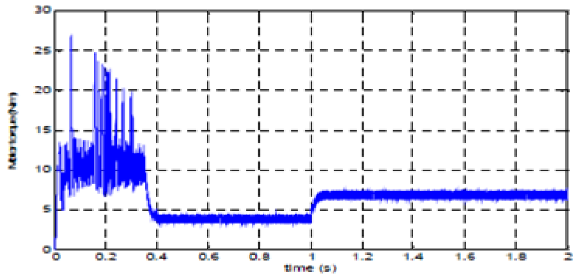

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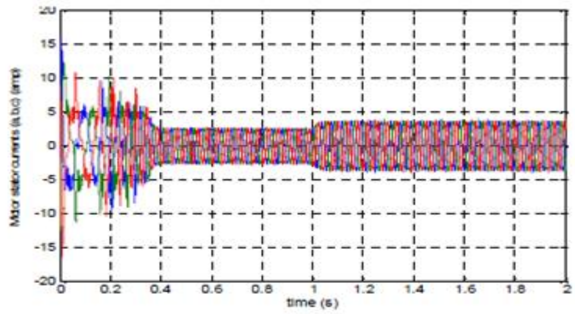

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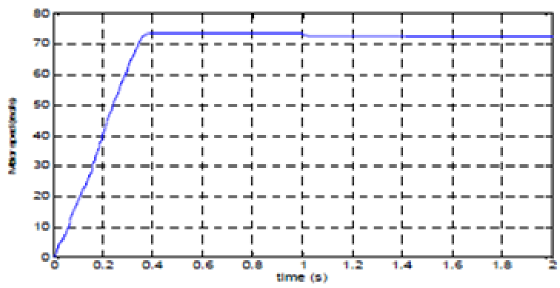

(d)

Fig. 7 Performance of IM under load torque step change (3:7 N.m.) (a) d-q stator flux (b) Developed motor torque (c) Three phase stator motor current (d) Motor speed

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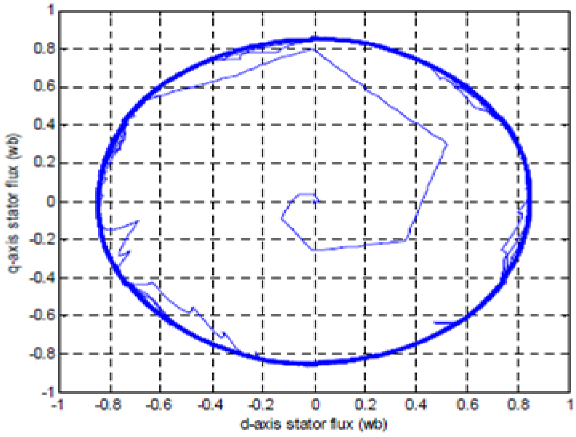
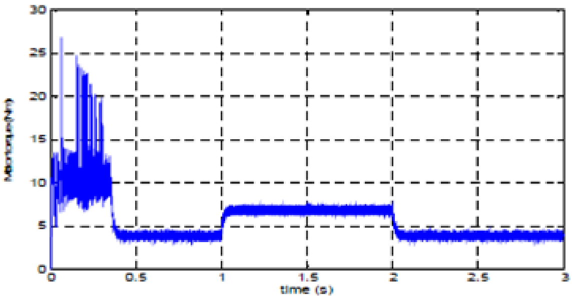


(a)



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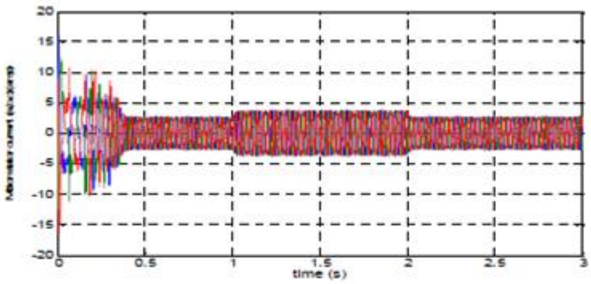

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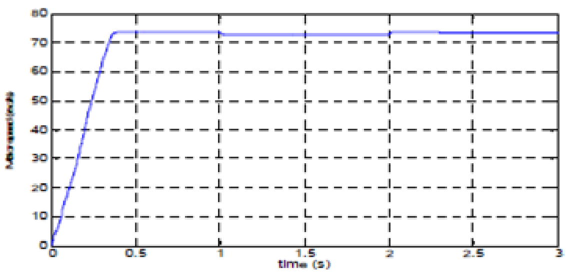

(d)

Fig. 8 Performance of IM under step change in load torque (a) d-q stator flux (b) Developed motor torque (c) Three phase stator motor current (d) Motor speed

Conclusion

The presented DTC system supplied from photovoltaic array system can be used in several purposes. Accepted practical system with no need for co-ordinate transformation, voltage, or current decoupling and no need for an encoder is obtained. The result shows that the proposed current based tracker has fast and well damped response. Simulation and experiment results are presented to demonstrate the potential of the proposed scheme. It has been shown that the proposed scheme has several advantages such as, small steady state error, fast response, and small overshoot with disturbance.

APPENDIX

The induction motor is a three-phase squirrel cage and has the following data:

TABLE I
A THREE-PHASE SQUIRREL CAGE INDUCTION MOTOR DATA

Rated power	1.1 kW
No. of pole pairs	2
Stator resistance	7.4826 Ohm
Rotor resistance	3.6840 Ohm
Mutual inductance	0.4114 Henry
Stator leakage inductance	0.0221 Henry
Rotor leakage inductance	0.0221 Henry
Motor speed	1500 rpm

TABLE II
ELECTRICAL CHARACTERISTICS OF A PV MODULE

Maximum power (P_{max})	180 W
Voltage at Maximum power (V_{max})	35.7 V
Current at Maximum power (I_{max})	5 A
Open circuit voltage (V_{oc})	44.1 V
Short circuit current (I_{sc})	5.5 A
Rated temperature (T)	298 Kelvin
Number of cells	72 in series

References

[1] G. M. Masters, "Renewable and efficient electric power systems" ISBN 0-471-28060-7, 2004 by John Wiley & Sons, Inc., Hoboken, New Jersey.

[2] Paul A. Lynn, "An introduction to photovoltaics" ISBN 978-0-470- 74560-1, 2010 BY John Wiley & Sons Ltd, West Sussex, PO19 8SQ, United Kingdom.

[3] M. G. Wanzeller, R. N. C. Alves, J. V. D. F. Neto and W. A. D. S. Fonseca, "Current Control Loop for Tracking of Maximum Power Point Supplied for Photovoltaic Array," IEEE Transactions on

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International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Instrumentation and Measurement, Vol.53, No.4, pp.1304-1310, August 2004.
[4] Rong-Jong Wai, Wen-Hung Wang, and Chung-You Lin, "High- Performance Stand-Alone Photovoltaic Generator System," IEEE Transactions on Industrial Electronics , Vol. 55, No. 1, pp.5-14, January 2008.
[5] J. H. R. Enslin, M. S. Wolf, D. B. Snyman, and W. Swiegers,"Integrated Photovoltaic Maximum Power Point Traking Converter," IEEE Transactions on Power Electronic, Vol. 44, No.6, pp.769-773, December 1997.
[6] H. S. H. Chung, K. K. Tse, S. Y. R. Hui, C. M. Mok and M. T. Ho,"A Noval Maximum Power Point Traking Tracking Technique for Solar Panels Using a SEPIC or Cuk Converter," IEEE Transactions on Power Electronic, Vol. 18, No.3, pp. 717-724, May 2003.
[7] W. Libo, Z. Zhengming, and L. Jianzheng, "A Single-Stage Three-Phase Grid-Connected Photovoltaic System with Modified MPPT Method and Reactive Power Compensation," IEEE Transactions on Power Electronic, Vol. 22, No.4, pp. 881-886, December 2007.
[8] N. Femia,G. Petrone, G. Spagnuolo, and M. Vitelli,"Optimization of Perturb and Observe Maximum Power Point Traking Method," IEEE Transactions on Power Electronic, Vol. 20, No.4, pp. 963-972, July 2005.
[9] M. Veerachary, T. Senjyu, and K. Uezato, "Feed Forward Maximum Power Point Tracking of PV Systems Using Fuzzy Controller," IEEE Transactions on Aerospace and Electronic System,Vol. 38, No. 3, pp.969-981, July 2002.
[10] C.-C. Chu, and C.-L. Chen, "Photovoltaic Cells: A Sliding Mode Control Approach," Journal of Solar Energy, Vol. 83, No. 8, pp.1370- 1378, 2009.